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Waste Management Pinch Analysis (WAMPA) with Economic Assessment

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Conventional Pinch Analysis (PA) had been widely used d to define the target (demand chain) of a process system based on the information of stream quantities and quality (supply chain) for a micro-scale industries planning. With contrast to the conventional Pinch approaches, regional Solid Waste Management (SWM) strategy are often performed via optimisation tool which is often optimized in a "black-box" optimization mathematical model. However, to enhance understanding and comprehension of the strategy, a visual technique like Pinch Analysis would be vital. A new application of Waste Management Pinch Analysis (WAMPA) for carbon emission was proposed to identify waste management strategies based on specified landfill reduction target and carbon emission target. This study used WAMPA methodology to analysis the effect of recycling target and cost reduction target towards waste management planning.

1. Introduction

The high dependency of landfill, low recycling rate, the abundant of municipal solid waste (MSW) as a potential resource for energy and value-added product, and the poor practice of waste management have stimulated the transformation of Malaysia's municipal solid waste management (MSWM) from a conventional MSWM towards an integrated, sustainable, efficient, and cost effective MSWM system. The government of Malaysia had spent millions of RM on waste management. About RM 662 M was spent in year 2005 on solid waste management and it is estimated to rise to RM 1.043 B by year 2020.The increase of management cost is due to the investment cost of technologies and programs for the solid waste management mainly through sanitary landfill and partly through incineration. Approximately half of the Malaysia capital investment of MSWM is spent on the waste treatment and disposal technologies. Such expenditure transpires the need to find alternative solutions to achieve effective and sustainable MSWM with minimal cost.

Systems modelling for supporting decision making in waste management has been developed since the 1970s including simulation models, forecasting models, cost-benefit analysis, and optimization models. Those models however are complicated mathematical equations that required the specific modelling knowledge to development the models. To enhance understanding and comprehension of the strategy, a visual technique would be vital. Among the optimization techniques present, Pinch Analysis (PA) poses the advantage of simplified complicated mathematical modelling while presented visual results is useful for communication of decision makers and stakeholders, had been widely applied through many applications. PA was first pioneered for Heat Integration problems in chemical engineering process (Linnhoff and Flower, 1978), it is now has been extended beyond energy applications to other areas. El-Halwagi and Manousiouthakis (1989) first adopted the PA into mass exchange networks of a chemical process. PA was further adapted in power system planning by Bandyopadhyay (2011) to design an off-grid PV/Battery

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system. Wan Alwi et al. (2012) continue to improve the power for hybrid renewable energy sources. Ho et al (2014) performance a novel power pinch analysis approach by employs new ways of utilising the demand and supply Composite Curve methods for the design of off-grid hybrid energy systems. Giaouris et al. (2014) continue to improve the work on Power PA by introduced Power Grand Composite Curves (PGCC) method to adaptively adjust the system operation in short-term power requirements. Other than energy and power, Manan et al. (2004) proposed the used of Water Pinch to target the minimum water flow rate. Ng et al. (2007) adopted Water Pinch for wastewater recycling issue. Multiple Utility Pinch analysis studied by Chezghani (2012) to simultaneously target the multiple utilities and perform heat allocation between the utilities and the individual process streams.

Conventional PA is used to define the target (demand chain) of a process system based on the information of stream quantities and quality (supply chain) for a micro-scale industries planning. With contrast to the conventional Pinch approaches, Tan and Foo (2007) developed Carbon Emission Pinch Analysis (CEPA) to address the carbon emission constraints issue arise from energy sectors for macro scale regional planning. Crilly and Zhelev (2008) applied CEPA method to the Irish electricity generation sector. CEPA used a set of initial target to meet new set target based on the existing strategies. In CEPA for carbon emission reduction, the carbon reduction target from the energy sector was set based on national or regional development plan, then emissions reduction action is decided to achieve the set target. CEPA extends the conventional PA technique from industrial sites to broader macro-scale applications into electricity generation sector to optimise the generation mix based on demand/emissions targeting (Tan and Foo, 2007)

A new application of Waste Management Pinch Analysis (WAMPA) for carbon emission was proposed by Ho et al. (2015) where it identified waste management strategies (waste to energy (WTE), recycling, reduce, reuse) based on specified carbon emission target. In this article, the general methodology of WAMPA that was proposed by Ho et al. (2015) is reviewed and explained. Then the novel method is be used to examine the implications of the recycling target and cost reduction target on the generation mix and emissions levels in 2025 for a case study of in Malaysia.

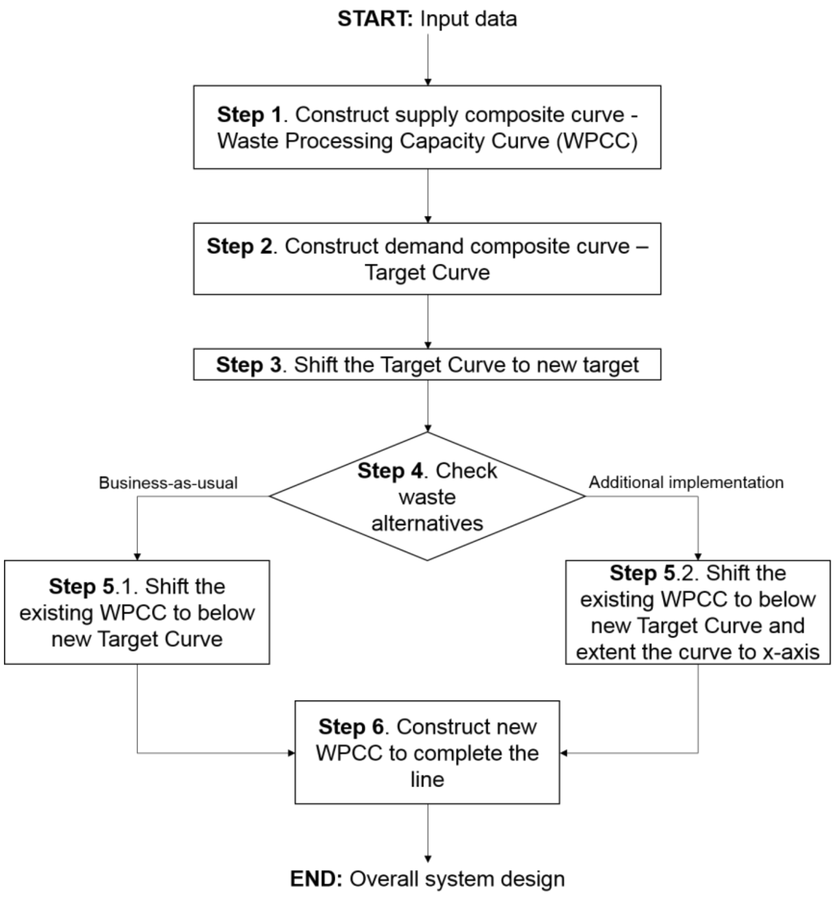

Figure 1: General procedure to implement the Waste Management Pinch Analysis (WAMPA) approach

2. Waste Management Pinch Analysis (WAMPA) for carbon emission reduction and landfill reduction target

WAMPA is designed base on CEPA which requires the user to set a target and construct a Supply Curve base on existing implemented strategies to meet a newly set target. A brief explanation of the technique for WAMPA is presented here, however Ho et al. (2015) provided a comprehensive explanation of the methodology for constructing the Composite Curve in WAMPA.
The basic techniques of WAMPA are based on the demand and supply in waste management, where the demand referred to the target while the supply referred to the strategies. In the case of WAMPA, aside from carbon emission targeting, it also includes landfill reduction target. The Supply Curve known as the Waste Processing Capacity Curve (WPCC) in WAMPA represents waste management strategies which is grouped into three categories: the carbon emission from Landfill Curve, carbon emission from WTE Curve and No Emission Strategies Curve or better described as the 3R Curve (reduce, reuse, and recycle). Figure 1 explains the general procedure to execute WAMPA while Figure 2 illustrates the representation of each Supply Curve.
The existing WPCC was constructed by plotting the cumulative quantify of waste processing amount for different processing strategies such as landfilling, WTE and 3R as shown in Step 1 in Figure 1. Next, a target of carbon emission reduction and reduction of waste to landfill were set (Step 2). Once the target is set, gradually shift a part (decided based on landfill reduction target) of the existing WPCC from baseline landfill carbon emission to the new target (Step 3). At this point, the WPCC line is located to be below the target, working from the target to the origin. It is then followed by shifting a portion of the existing WTE Curve to the new curve from the end of the Landfill Curve of WPCC (Step 4). The WTE Curve is extended to touch the x-axis, the extended portion of the curve represent additional WTE strategies to be implemented (Step 5). Finally, the PA for waste management is completed by extending the Curve (which is now along the x-axis) to the existing 3R Curve, the extended portion of the curve represent additional alternatives 3R initiatives to be implemented. (Step 6).
In summary, WAMPA methodology for carbon emission reduction and landfill reduction of waste management is capable to identify the capacity of each group of strategy and capable to provide meaning and illustration to the effect of changing of target toward the needs of each strategy. However it posed weakness that do not include cost factor, which is addressed in this paper.

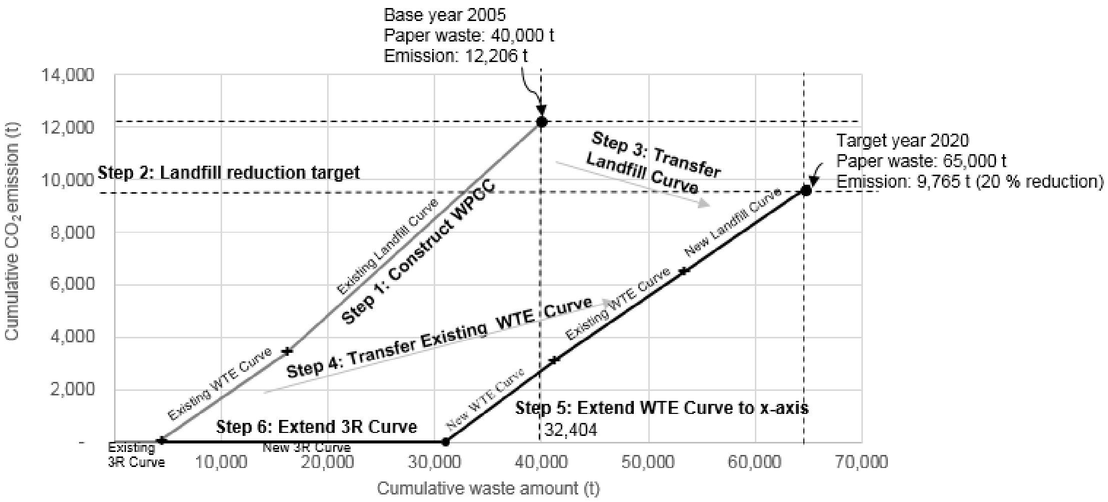

Figure 2: WAMPA for paper waste management for carbon emission reduction and landfill reduction target (Ho et al., 2015)

3. WAMPA for cost reduction and recycling target

For a developing country like Malaysia, a large portion of national budget is devoted to waste management services, mainly for waste collection and landfill maintenance. By adapting the WAMPA methodology, a case study to examine the management cost reduction with recycling target in waste management planning reduction is presented.

Table 1: oData for WAMPA analysis with cost reduction and recycling target

Information	2005	2020
MSW (t)	230,000	300,000
MSW to landfill (%)	80	-
MSM to recycling (%)	15	40
MSW to composting	5	-
Cost of landfill ($/t)	80	
Cost of recycling ($/t)	20	
Cost of composting ($/t)	10	
Cost reduction target (%)	-	20

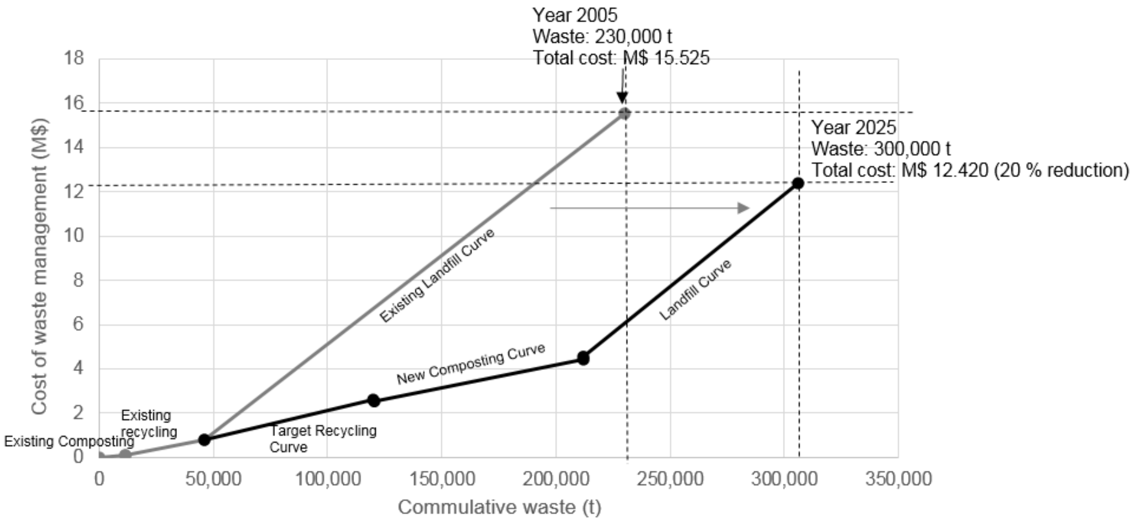

Figure 3: WAMPA analysis for management cost reduction and recycling target

Table 1 presents the information for waste management in a case study with hypothetical data to showcase the methodology. It can be observed that in year 2005, 80 % of MSW was send to landfill while only 15 % of waste was recycled and 5 % was composted. In the target year 2025, the management cost is set to reduce by 20 % from baseline (2005) and recycling target is aimed to increase to 40 %. However, the share of waste allocation to other alternatives (in this case study are composting and landfill) remain unknown. WAMPA is performance based on this information to identify the capacity of each group of strategy (landfill and composting).

Figure 3 illustrated the result from WAMPA. Based on the case study, it is suggested to meet up to 20 % management cost reduction and recycling rate increment by 40 %, additional 69,500 t in capacity of composting technology is required, which also indicated the increase of composting in WMS to 27 %. Other the other hand, it also suggest a reduction of waste to landfill by 85,000 t, a 40 % reduction in landfill.

4. Sensitivity analysis for recycling target

To further illustrate the effect of recycling target on the waste management planning, a sensitivity analysis is carried out by adjusted the recycling target ± 20 %. The result is illustrated in Figure 4.

Based on Figure 4, by increasing the waste allocation for recycling from 40 % to 60 % (counter measures (CM) 60 %), the amount of waste allocation for new composting increases to 45,000 t with decrement of cost from 7 % to 4 %. While the new landfill cost also decreases to from 61 % to 48 % due to the decrease of waste to landfill (Figure 5), in order to maintain the targeted waste management cost of $ 12,420,000. On the contrary, by reducing recycling target to 20 %, the amount of waste allocation for new composting and landfill increases to 165,000 t and 75,000 t, as compared to CM 40 %.

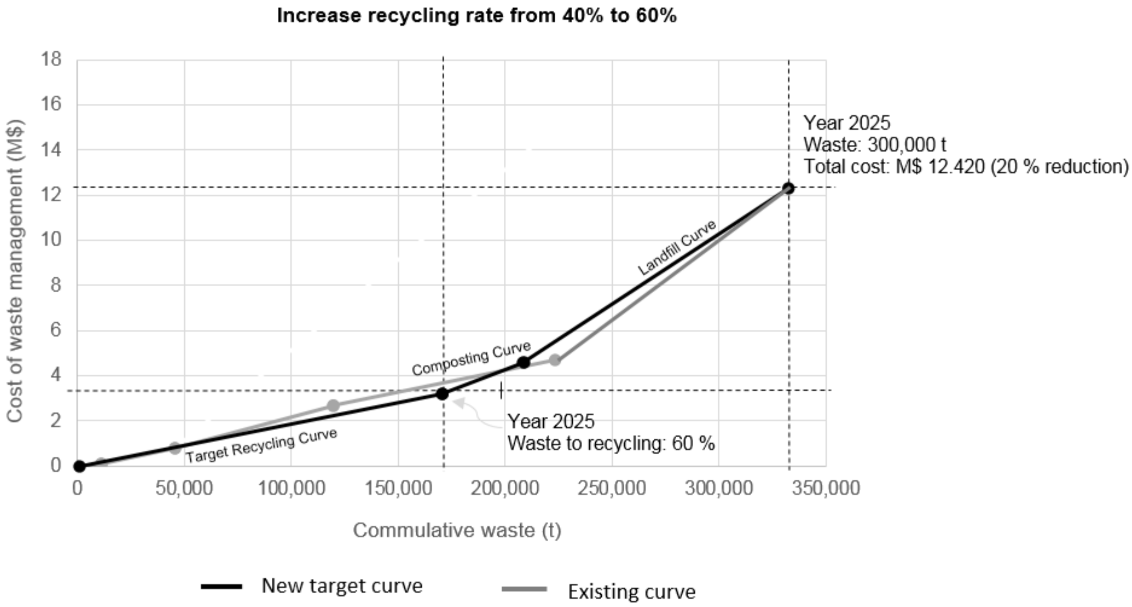

Figure 4: Effect of increasing recycling target towards management strategies

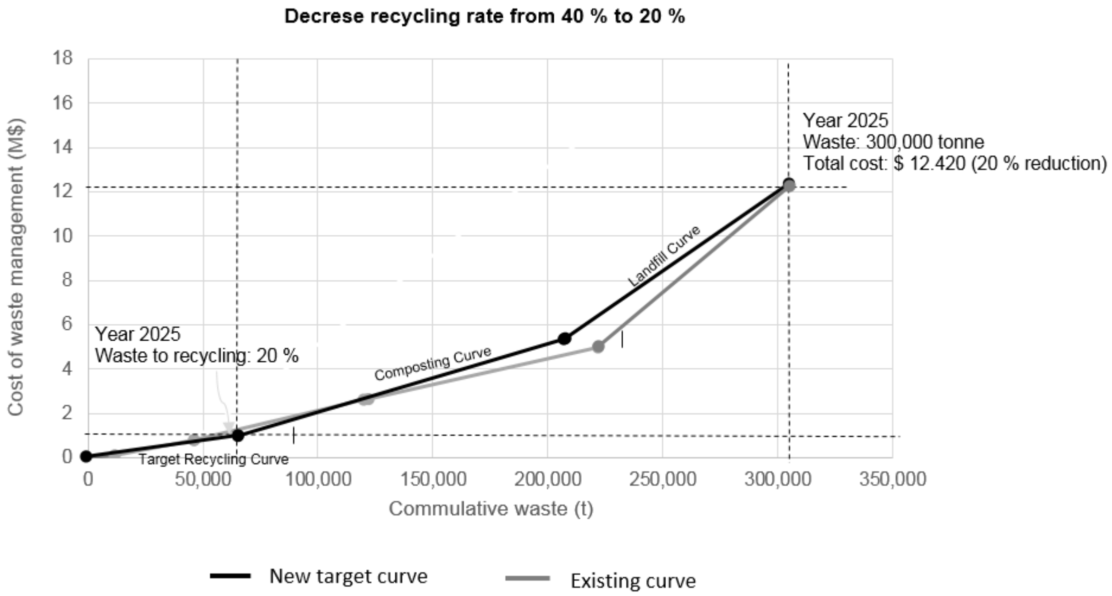

Figure 5: Effect of decreasing recycling target towards management strategies

5. Conclusion

Base on the overall outcome of the study, WAMPA is capable to identify the capacity of each group of strategy with the desired target through graphical presentation. It is also capable to provide meaning and illustration to the effect of changing of target toward the needs of each strategy. Nevertheless, it poses a weakness to determine multiple targets (more than two) simultaneously due to its limitation of two dimension.

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